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MIPR NO: 94MM4523

TITLE: Vocal Cord Function and Voice Quality Evaluation of Active Duty U.S. Army Drill Instructors

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Washington, DC 20307

REPORT DATE: October 1994

TYPE OF REPORT: Midterm

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Frederick, Maryland 21702-5012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1994

3. REPORT TYPE AND DATES COVERED
Midterm (15 Feb 94 - 30 Sep 94)

4. TITLE AND SUBTITLE
Vocal Cord Function and Voice Quality Evaluation of Active Duty U.S. Army Drill Instructors

5. FUNDING NUMBERS
94MM4523

6. AUTHOR(S)
Eric Mann, MAJ; Jeffrey Paffrath, CPT

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Walter Reed Army Medical Center
Washington, DC 20307

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick
Frederick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS
Vocal Cord, Quality

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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INTRODUCTION

Leaders of small military units readily admit to deterioration or even loss of voice during training and field exercises. Degradation of voice quality can severely impair field communication, and could potentially adversely affect a leader's ability to safely and effectively command his/her unit. Frequently, such voice changes resolve only after prolonged voice rest, and repeated episodes have led to permanent vocal cord pathology and socially unacceptable voice quality in some individuals.

Anatomic changes in the vocal cords following periods of acute and chronic voice abuse have been previously documented in the literature to include edema, nodules, polyps, contact ulcers, hemorrhage, and scarring (1,2). No studies to date, however, have addressed the chronology of voice and vocal cord changes that occur during voice abuse. A clear understanding of the pathophysiological changes that occur during an episode of voice abuse may be helpful in developing strategies to combat voice impairment and vocal cord injury.

To document vocal cord pathological changes, clear visualization of the vocal cords is essential. The standard office evaluation in the past relied on "indirect" visualization of the larynx using a laryngeal mirror. The reflected image of the vocal cords is small but adequate for diagnosis of gross anatomic or functional changes. Flexible fiberoptic endoscopes passed transnasally are also valuable in evaluating patients with hyperactive gag reflexes and anatomic configurations which preclude a thorough mirror exam such as an overhanging epiglottis or anterior larynx.

The relatively recent addition of videostroboscopy to the diagnostic armamentarium has dramatically improved the otolaryngologist's ability to identify vocal cord pathology (3). Stroboscopic technology allows the examiner to slow the apparent vibration of the vocal cords to a level which is perceptible to the human eye. Thus, detailed evaluation of the vibratory wave of the cords and detection of subtle anatomic and functional changes is possible. One can observe the effects of vocal fold edema, polyps, nodules, scar tissue, and hyperfunction on the vibratory pattern of the larynx. Furthermore, a permanent record of the examination is produced for detailed analysis and comparison to subsequent examinations. Sataloff et al. demonstrated that the addition of videostroboscopy in the evaluation of hoarse professional speakers had proven helpful in 47% of individuals and actually resulted in a change of diagnosis in 18% of these cases (4,5). Woo et al.(6) observed that videostroboscopy contributed significant diagnostic information in 27% of cases and led to change in diagnosis in 10%. Thus, videostroboscopy has proven usefulness in evaluation and documentation of vocal fold pathology.

Another diagnostic tool available for the study of voice quality is acoustic analysis. Acoustic voice analysis provides an indirect measure of the vibratory patterns of the vocal folds, in addition to vocal tract shapes and the changes in those shapes over time. Measurements include various derivatives of frequency, intensity, and time. Interpretation of data is made relative to normative data bases and is subject to changes based on age, sex, type of phonation and voice training. Combination of acoustic measures with videostroboscopic measures is an ideal marriage (2). The stroboscopic images help explain the source of the acoustic findings, while the acoustic parameters help to quantify the qualitative observations from the stroboscopic recordings.

The intent of this study is to provide the first detailed chronologic record of laryngeal tissue alterations and acoustical voice changes which occur during a period of acute voice abuse. Furthermore, attempts will be made to identify "risk" factors such as specific voice behaviors, underlying medical conditions (eg. gastroesophageal reflux), or dietary habits (eg. caffeine intake) which may predispose an individual to the deleterious effects of vocal abuse. The conclusions reached from this project may provide a basis for formulating treatment strategies to combat voice changes associated with voice abuse.

BODY

General Overview of Experimental Methods

U.S. Army Drill Instructors (DI) are considered a high risk population for voice change because of their vocal abusive and misusive behaviors. These behaviors include prolonged periods of loud talking/yelling and talking with excessive laryngeal force and strain. Because their activities involve cycles of intense training with intervening rest periods of several weeks, drill instructors are ideal models for the chronological studies of voice abuse. The selected study population consisted of 44 active duty drill instructors from four companies at Fort Jackson, S.C. actively involved in the training of new military recruits. Exclusion criteria included a history of laryngeal surgery, known laryngeal pathology, or the use of inhaled or oral steriods. Enrollment of the instructors into the protocol occurred prior to the commencement of a training cycle during which time they had been at relative voice rest for a period of two to three weeks.

After obtaining informed consent, each of the subjects was asked to complete a medical history and a voice case history form to help identify pre-existing medical or vocal conditions, medically and/or vocally abusive behaviors (eg. smoking, caffeine ingestion), and specific information about voice changes relative to their duties. A videostroboscopic examination was performed during this initial evaluation to obtain a baseline recording of vocal anatomy and function prior to the onset of vocal abusive activities. Similarly, a high-quality baseline audio recording including a sustained "ahhh" and connected speech samples was obtained on each subject in a sound treated booth. All examinations and recordings were obtained in the Otolaryngology clinic at Montcrief Army Community Hospital, Ft. Jackson, S.C.

Subjects were then assigned to one of three groups for all subsequent examinations: early morning (0600-0700 hr), late morning (1100-1200 hr), and afternoon (1500-1600 hr). For the next five days, i.e., the first five days of the training cycle, the subjects reported to clinic at their assigned group time for audio recordings similar in content to the baseline recordings. Notes were also taken on their activities for that day and their subjective impressions of their own voice quality. On the final day, a videostroboscopic examination was also obtained for comparison to the baseline exam.

Preliminary Results of Acoustic Analyses of Audio Recordings

There has been limited research into the effects of prolonged or strenuous voice production that involves physical analysis of the acoustic signal, although studies of this type can now be found in the voice literature (7). A major component of the present project entails acoustic analyses of voice signals of the drill instructors over the period of training. The 44 subjects were stratified into three groups for which tape recordings were obtained in the early morning, late morning, or afternoon. This was done in order to control for the possible short term effects of extensive vocal use during the course of the day. Each subject was recorded at baseline and over the first five days of training in a sound treated room using a high quality digital tape recorder. The resulting audio recordings are now being analyzed at the Audiology and Speech Center at WRAMC.

Acoustic analysis is being carried out with the Kay Elemetrics Multidimensional Voice Analysis System. The analysis procedure first involves digitizing to computer a three-second sample of a sustained "ah" production at a sampling rate of 50 kHz. Automated software routines are then used to extract several different measures that represent the acoustic correlates of temporal stability of vocal fold vibration and perceived voice quality. We have selected a subset of 14 measures which should prove sensitive to any acoustic alterations in voice production that may occur over the period of drill instructor training. A software routine has been developed to automatically extract these measures from data files and read them in to a statistical spreadsheet (Minitab 10.0). These measures include percent vocal jitter and shimmer, fundamental frequency, measures of vocal tremor and relative magnitudes of the periodic versus aperiodic components of the signal. Normative data on each of the acoustic measures are available in the literature and through Kay Elemetric's testing with their own system. Our primary interest here is in time series effects related to prolonged strenuous use associated with drill instructor training.

Analysis and measurement of the acoustic data has now been completed on over half of the subjects. We are presently performing preliminary statistical analysis on these acoustic data and entering other types of data into the statistical spreadsheet. These other measures include coding for gender, smoking, vocal use ratings, and stroboscopic evaluation results. Preliminary results indicate that acoustic measures obtained on most subjects fall within normal limits for the full course of training. However, particular individuals appear to have undergone substantial vocal strain and fatigue as training progressed. This is illustrated in Figure 1 (Appendix I) which shows partial results for percent vocal shimmer measures on 24 subjects. Two subjects showed pronounced effects by the fourth day of testing, and a second two also appear well beyond normal limits at days 4 and 5. This type of observation may prove relevant for issues pertaining to job performance. For example, were the individuals with elevated vocal shimmer significantly handicapped during the latter phases of training corresponding to recording sessions 4-6? Also, there is a natural concern that these same individuals may have a high likelihood for long-term vocal abuse that could substantially impair their military careers. Results of stroboscopic analyses will be particularly relevant in this regard. More extensive analyses of the several acoustic measures in relation to other coded variables (e.g. stroboscopic measures or history of smoking) will be carried out in the coming months. These may reveal associations between different classes of variables which have predictive value for identifying individuals who are most likely to

experience adverse vocal reactions during the training cycle. Such information could provide an objective basis for vocal intervention with particular individuals.

Preliminary Analysis of Voice Recordings

Baseline and post-vocal abuse videostroboscopic recordings were available for analysis in 43 of the 44 patients. Thirty-nine of the patients were successfully imaged transorally with the rigid seventy degree telescope which allows better illumination and picture clarity than the transnasal flexible telescope examination which was performed in the remaining 4 individuals. Examination consisted of stroboscopy with the patient sustaining the vowel "eee" in various ways: high-pitched, low-pitched, low-to-high pitched glide, loud, and soft. As stated above, exams were obtained at baseline prior to voice abusive activity and on the fifth day of training.

For analytical purposes, the examinations are currently being rated by two independent reviewers, a speech pathologist with videostroboscopic expertise and a Ph.D. speech scientist. A specialized rating scale has been devised for evaluation of functional and anatomic changes which appear to be important features of voice abuse. Rated parameters include vocal fold closure, glottal gap, vocal fold edges, hourglass configuration, periodicity, amplitude of vocal fold excursion, mucosal wave, phase symmetry, edema, and erythema. Recordings are being rated in a randomized, blinded fashion with controls in place to combat the potential effects of rater fatigue, bias, etc.

Preliminary findings indicate progressive edema, erythema, aperiodicity, and vocal fold irregularity in individuals prone to the effects of voice abuse. Several patients demonstrated early polypoid changes of the free edge of one or both vocal cords. Another larger subset of drill instructors experiencing similar voice demands appears to be relatively resistant to the adverse effects of voice abuse on vocal cord appearance and function. Correlations of these visual findings with the acoustic analysis data, the medical surveys, and the voice questionnaires will be of great importance in understanding the pathophysiology of voice abuse and risks factors for the adverse effects of voice abuse.

CONCLUSIONS

. The series of changes in vocal cord structure and function which occur during periods of acute voice abuse are poorly understood. By documenting the anatomical and functional changes with videostroboscopy and acoustic analysis of voice recordings, this project endeavors to clarify the mechanisms of voice change that occur during voice abuse. An enormous quantity of data including over 250 voice recordings, 86 videostroboscopic examinations, and detailed questionnaires regarding pertinent medical and voice case histories for each of the 44 study participants have been collected and are currently being analyzed. Preliminary review of the data suggests that certain individuals are prone to the adverse effects of voice abuse on voice quality and vocal cord anatomy and function.

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Figure 1. Percent vocal shimmer across six days of testing for 24 subjects and 115 recording sessions. Different symbols indicate individual subjects. The horizontal line indicates the upper limit of normal performance as established by Kay Elemetrics. Data sets for days 4-6 are incomplete.